Fermilab Directorate

MEMORANDUM OF UNDERSTANDING FOR THE 2007-2009 TEST BEAM PROGRAM

T962: ArgoNeuT (Argon Neutrino Test)

Mini Liquid Argon TPC in the NuMI Beam

October 3, 2007

INTRODUCTION

This MOU describes a test of a small prototype Liquid Argon time projection chamber (LArTPC). The prototype, an approximately 500 liter "mini-LArTPC," will be exposed to the on-axis NuMI neutrino beam in the NuMI near underground enclosure. The project is funded primarily through an NSF CAREER grant for B. Fleming of Yale University. Further details on the project can be found at http://t962.fnal.gov.

This memorandum is intended solely for the purpose of providing a work allocation for Fermi National Accelerator Laboratory and the participating universities and institutions. It reflects an arrangement that is currently satisfactory to the parties involved. It is recognized, however, that changing circumstances of the evolving research program may necessitate revisions. The parties agree to negotiate amendments to this memorandum to reflect such revisions.

MOTIVATION

CP Violation in the neutrino sector, the indicator of a possible explanation for our matter dominated universe, may be associated with the last unknown mixing angle of the 3x3 PMNS matrix, θ_{13}. The next generation of long-baseline neutrino oscillation experiments will be an order of magnitude more sensitive to θ_{13} beyond existing measurements and, if non-zero, its associated CP violation parameter, δ. In particular, a NuMI Off-axis, long baseline experiment, or a long-baseline, wide-band beam from Fermilab to DUSEL will be ideal in pursuing this measurement beyond what the NOvA experiment will tell us. The T962 project is research and development towards using Liquid Argon TPC detectors for this program.

The LArTPC will be exposed to the on-axis LE NuMI neutrino beam, a flux with energy range 0.1 to 10 GeV and peaking at 3 GeV. Only one other LArTPC, the 50 liter ICARUS prototype, has been exposed to a neutrino beam - the much higher energy 24 GeV NOMAD neutrino beam. This NuMI data set will be invaluable for a first look at low energy neutrino interactions, as a test of collecting a neutrino interaction data set, and in reconstruction and analysis studies. The interest in the 50 liter data set from its run ~10 years ago is a good indicator for the interest levels for this LArTPC run.

What makes this test a crucial step beyond the 50 liter run is the increased size of the TPC and therefore larger, contained sample and the more relevant low energy beam for next generation neutrino oscillation studies.

Small scale TPC prototypes are presently under construction at Fermilab and Yale. First cosmic ray tracks were recorded in the Yale TPC in April of 2007. This is the first time tracks have ever been observed in a LArTPC in the US. It is an important milestone that speaks to the success of future ventures, such as the T962 project described here. T962 builds on the experience of the programs at FNAL and Yale. It provides a large sample of actual neutrino interactions in a small TPC. As well, it tests long term running stability and underground operation of the detector and support systems.

PROJECT DESCRIPTION

The mini-LArTPC will sit just upstream of the MINOS near detector, using the MINOS detector as a range stack to measure uncontained long-track muons from muon neutrino interactions in the TPC. The TPC, plumbing, electronics, and support equipment can fit on a support structure like that used for PEANUT which presently sits just upstream of the MINOS near detector. As PEANUT operates without disturbing the MINOS experiment, it is anticipated that this experiment will do so as well.

The design of the TPC vessel is determined by maximizing the active volume within the total allowable volume of Liquid Argon. The TPC dimensions are approximately 0.5m x 0.5 m x 1m. It is housed in a cylindrical cryostat sitting on its side. Signal feed throughs, purity monitor electronics and optical fiber, and support equipment are mounted on a flange on the top of the vessel. This configuration maximizes containment for forward events, the majority of the events in the detector.

The ~250 liter LArTPC active volume will see ~300 charged current muon neutrino interactions per day, with nominal intensity of the NuMI neutrino beam. The exact ratio of length to radius of the cylinder will be optimized to best contain protons and neutral pions from the neutrino interaction vertexes. The average length of proton and pion tracks for 1-3 GeV neutrino interactions is approximately 10 cm and 10-20 cm respectively. Neutral pions are harder to contain as they decay to gammas which then pair produce to signal a neutral pion. The radiation length of liquid argon is 14 cm, making this detector less efficient for containing neutral pions than charged particles. Nevertheless, with so many events in the detector, sizable samples of contained events are expected.

Support components necessary for the TPC operation include purification and recirculation systems, ODH safety system, and plumbing for LAr, simple trigger and veto, data acquisition, and electronics. These components will be constructed or borrowed from Yale's existing LArTPC prototype. The electronics will be designed and constructed by Michigan State University and Fermilab.

T962 underwent a PPD Review in May 2007. The committee responded very favorably to the project. The charge to the committee and their report can be found in the appendices.

I. PERSONNEL AND INSTITUTIONS:

Scientific spokesperson: B. T. Fleming, Yale University
Fermilab liaison: R. Rameika

The group members at present are:

1.1 Yale University: C. Anderson, B.T. Fleming, D. Gerstle, S. Linden, M. Soderberg, J. Spitz
Other commitments: MiniBooNE: C. Anderson, B.T.Fleming, S. Linden, M. Soderberg,

1.2 Fermilab: B. Baller, C. James, R. Rameika, N. Saoulidou.
Other commitments: MINOS: C. James, R. Rameika, N, Saoulidou
NOvA: R. Ramieka, N. Saoulidou

1.3 Michigan State University: C. Bromberg, D. Edmunds
Other commitments: NOvA: C. Bromberg

1.4 University of Texas at Austin: Karol Lang
Other commitments: MINOS, NOvA

1.5 L'Aquila University/Gran Sasso National Laboratory: Flavio Cavanna, Ornella Palamara, Francesco Arneodo
Other commitments: ICARUS, WARP

II. EXPERIMENTAL AREA, BEAMS AND SCHEDULE CONSIDERATIONS

2.1 LOCATION

2.1.1 The mini-TPC and support equipment will be assembled first in PAB. Installation underground may occur before the end of 2007.

2.1.2 The beam exposure test is to take place in the MINOS near detector hall. There is a small area immediately upstream from the MINOS near detector where the PEANUT test beam experiment is presently located. The test vessel and support equipment will be enclosed within a box like the PEANUT box enclosure and, like PEANUT, raised off the ground so that the test vessel is on axis and on the beam center.

2.1.3 This is the future location for the MINERvA experiment. It is anticipated that this test will take place, upstream of the MINOS ND up until the shutdown in 2008, before the MINERvA experiment begins installation. No location for the operation of T962 after this time has been identified, and will be the subject of a future discussion and possible amendment to this MOU.

2.1.4 Access to a computer network connection will be necessary.

2.1.5 Access to a copy of the beam timing signal will be necessary.

2.2 BEAM

2.2.1 This test utilizes the NuMI beam. Any of the NuMI beam tunes are acceptable.

2.2.2 Data from the MINOS near detector will be combined with data from this small LArTPC. This method of using the MINOS near detector as a muon range stack has worked successfully for the PEANUT experiment. R. Rameika is the expert on combining the data sets on PEANUT and will be the expert here.

2.3 SETUP

2.3.1 The LArTPC detector and support systems will be installed and commissioned in PAB prior to installation underground.

2.3.2 Crane operators will be needed to lower the LArTPC device into the MINOS hall.

2.3.3 Additional equipment (computers, miscellaneous equipment) will be lowered using the elevator.

2.3.4 There is no significant cabling needed for the LArTPC apparatus.

2.3.5 The hall crane will be used to lift the mini-LArTPC.

2.3.6 An ODH safety system will be installed in the MINOS hall as per the ODH analysis.

2.4 SCHEDULE

2.4.1 Design, construction, and component testing of the detector and support material will take place from October 2007 to December 2007.

2.4.2 Testing of the vessel components began in June of 2007 in PAB and will continue through commissioning of the vessel and components in Dec of 2007.

2.4.3 Installation in the MINOS near detector hall, underground, will take place as soon as possible. If there is no construction or testing delay, the underground installation will occur before the end of calendar 2007.

2.4.4 Data taking will take place until the 2008 shutdown. The footprint of T962 is designed so that if there is enough beam downtime such that MINERvA can install their detector stand before the 2008 shutdown, T962 can continue running between the MINERvA detector stand and the MINOS Near Detector.

III. RESPONSIBILITIES BY INSTITUTION - NON FERMILAB

Yale University

3.1	LArTPC Cryostat	$155k
3.2	Feedthroughs on cryostat for HV and electronics	$3k
3.3	Cryogenics and plumbing system	$40k
3.4	Data acquisition and Trigger system	$3k
3.5	Purity Monitor, vessel, and electronics	$1k
3.6	Xenon lamp for purity system	$5k
3.7	Wire Chambers and field cage	$3k
3.8	Argon supply total	$3k
3.9	Vacuum system including slow monitoring and vacuum pump	$10k
3.10	Support structure for Cryostat and related materials	$2k

IV. RESPONSIBILITIES BY INSTITUTION - FERMILAB

4.1 Fermilab Accelerator Division

4.1.1 The T962 project does not require Accelerator Division support.

4.2 Fermilab Particle Physics Division

4.2.1 Bartoszek Engineering will design the cryostat and provide an engineering note per FESHM 5031. The PPD Mechanical Department will be responsible for the safety analysis of the LArTPC.

4.2.2 Bartoszek Engineering will design the mechanical support structures for the LArTPC and will provide an engineering note documenting the design that is suitable for use in a safety review. The PPD Mechanical Department will be responsible a safety review based on this documentation.

4.2.3 PPD will fabricate G10 frames for the TPC. PPD will also provide lab space and access to a winding machine for the construction of the TPC, and will provide minimal technician support during TPC construction.

4.2.4 PPD will be responsible for moving the equipment into the MINOS hall and for rigging and handling of the equipment into its final location.

4.2.5 PPD will be responsible for materials, installation, and technical support for the underground exhaust system.

4.2.6 The PPD ES&H Department will assist in all of the necessary safety reviews.

4.2.7 PPD will coordinate access into the MINOS tunnel.

4.2.8 PPD will contribute the electronics M&S costs of $50k and continued support for Dan Edmunds (of MSU) for this work

4.2.9 Summary of Particle Physics Division costs:

Type of Funds	Equipment	Personnel (person-weeks)
Electronics M&S	$50k	
Mechanical Engineering		3.0 engineer
Cryogenic engineering		12.0 engineering & drafting
Pipe Fitting and Welding	$5k	6.0 tech & welding
Ventilation fans & ductwork		4.0 tech
Existing piping (300 ft)		
Lab 8 technical support for TPC Construction (G10 frames)		3.0 tech
Lab 6 technical support for TPC Construction		3.0 tech
Pressure Vessel Safety		2.0 engineer
Rigging, Support, Installation Analysis		2.0 engineer
Installation		4.0 tech
Commissioning & operational support		6.0 cryo engineer & tech
Total new items	$55k	21.8

4.3 Fermilab Computing Division

4.3.1 An Ethernet connection underground to the Data Acquisition computer will be necessary.

4.3.2 Low and high voltage power supplies (from PREP).

Type of Funds	Equipment	Operating	Personnel (person-weeks)
Total existing items	[$10.0K]	$0K	0.0
Total new items	$0.0K	$0K	0.2

4.4 Fermilab ES&H Section

4.4.1 Assistance with safety reviews.

V. SUMMARY OF COSTS

Source of Funds ($k)	**Equipment**	**Operating**	**Personnel** (person-weeks)
Particle Physics Division	$55k	0	21.8
Accelerator Division	0	0	0
Computing Division	0	0	0.2
Totals Fermilab	$55.0k		22
Totals Non-Fermilab	$225.0k		

VI. SPECIAL CONSIDERATIONS

6.1 The responsibilities of the T962 Spokesperson and procedures to be followed by experimenters are found in the Fermilab publication "Procedures for Experimenters" (PFX) (http://www.fnal.gov/directorate/documents/index.html). The Physicist in charge agrees to those responsibilities and to follow the described procedures.

6.2 To carry out the experiment a number of Environmental, Safety and Health (ES&H) reviews are necessary. This includes creating a Partial Operational Readiness Clearance document in conjunction with the standing Particle Physics Division committee. The T962 Spokesperson will follow those procedures in a timely manner, as well as any other requirements put forth by the division's safety officer.

6.3 All regulations concerning radioactive sources will be followed. No radioactive sources will be carried onto the site or moved without the approval of the Fermilab ES&H section.

6.4 All items in the Fermilab Policy on Computing (http://computing.fnal.gov/cd/policy/cpolicy.pdf) will be followed by experimenters.

6.5 The T962 Spokesperson will undertake to ensure that no PREP and computing equipment be transferred from the experiment to another use except with the approval of and through the mechanism provided by the Computing Division management. They also undertake to ensure that no modifications of PREP equipment take place without the knowledge and consent of the Computing Division management.

6.6 Each institution will be responsible for maintaining and repairing both the electronics and the computing hardware supplied by them for the experiment. Any items for which the experiment requests that Fermilab performs maintenance and repair should appear explicitly in this agreement.

6.7 If the experiment brings to Fermilab on-line data acquisition or data communications equipment to be integrated with Fermilab owned equipment, early consultation with the Computing Division is advised.

6.8 At the completion of the experiment:

6.8.1 The T962 Spokesperson is responsible for the return of all PREP equipment, Computing equipment and non-PREP data acquisition electronics. If the return is not completed after a period of one year after the end of running the T962 Spokesperson will be required to furnish, in writing, an explanation for any non-return.

6.8.2 The experimenters agree to remove their experimental equipment as the Laboratory requests them to. They agree to remove it expeditiously and in compliance with all ES&H requirements, including those related to transportation. All the expenses and personnel for the removal will be borne by the experimenters.

6.8.3 The experimenters will assist the Fermilab Divisions and Sections with the disposition of any articles left in the offices they occupied, including computer printout and magnetic tapes.

6.8.4 An experimenter will report on the test beam effort at a Fermilab All Experimenters Meeting.

SIGNATURES:

_____ / / 2007
Bonnie Fleming (PI), Yale University

_____ / /2007
Rob Plunkett, Co-Spokesperson of MINOS, Fermilab

_____ / /2007
Catherine James, Coordinator of MINOS near cavern, Fermilab

_____ / / 2007
Greg Bock, Particle Physics Division

_____ / / 2007
Roger Dixon, Accelerator Division

_____ / / 2007
Victoria White, Computing Division

_____ / / 2007
William Griffing, ES&H Section

_____ / /2007
Hugh Montgomery, Associate Director, Fermilab

_____ / /2007
Stephen Holmes, Associate Director, Fermilab

APPENDIX I - Hazard Identification Checklist

Items for which there is anticipated need have been checked

Cryogenics		**Electrical Equipment**		**Hazardous/Toxic Materials**	
	Beam line magnets	x	Cryo/Electrical devices		List hazardous/toxic materials
	Analysis magnets		capacitor banks		planned for use in a beam line or experimental enclosure:
	Target	**x**	high voltage	x	Liquid Argon
X	Liquid Argon TPC		exposed equipment over 50 V		
Pressure Vessels		**Flammable Gases or Liquids**			
60cm	inside diameter	Type:			
30 psig	operating pressure	Flow rate:			
	window material	Capacity:			
	window thickness	**Radioactive Sources**			
Vacuum Vessels			permanent installation	**Target Materials**	
60cm	inside diameter		temporary use		Beryllium (Be)
1.5 atm	operating pressure	Type:			Lithium (Li)
	window material	Strength:			Mercury (Hg)
	window thickness	**Hazardous Chemicals**			Lead (Pb)
Lasers			Cyanide plating materials		Tungsten (W)
	Permanent installation		Scintillation Oil		Uranium (U)
	Temporary installation		PCBs	**X**	Other : **Liquid Argon**
	Calibration		Methane	**Mechanical Structures**	
	Alignment		TMAE	**X**	Lifting devices
type:			TEA		Motion controllers
Wattage:			photographic developers	X	scaffolding/elevated platforms: like existing PEANUT platform
class:		x	Other: Oxygen Deficiency Hazard		Others

APPENDIX II Electronics Rack Hazard Requirements
The electronics rack will be protected by Rack Protection Smoke Detection System, consistent with NuMI and COUPP electronics racks.

APPENDIX III Oxygen Deficiency Hazard Requirements
The mini-TPC will be designed to meet ODH class zero outside the containment system per FESHM 5064. The limited egress underground will be considered in this analysis. The preliminary ODH analysis for T962 is documented here:

http://lartpc-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=288.

APPENDIX IV LAYOUT OF THE mini-TPC TEST IN THE MINOS AREA.
Detector and support systems will be housed as in the existing PEANUT enclosure.

APPENDIX V: RUN PLAN.

1)	Rigging, installation, setup	2 week
2)	Argon transfer, commissioning	2 week
3)	Data taking	6-12 months

APPENDIX VI: PPD Review Charge and Report

T962 was reviewed by PPD in April of 2007. Below is the committee's report:

T962 Review 5/17/07
David Christian, Jim Kilmer, John Voirin, Leon Beverly, Robert Wagner, Adam Para, and Karen Kephart

The committee was asked to review and comment on a number of aspects of T962. Our responses are given in italics below each item.

1) The overall goals of the project and are they achievable in the proposed time frame.

The project is well motivated in the context of the larger LArTPC R&D effort at FNAL. The schedule as presented is very aggressive. The goals of the project can be met even if the schedule slips significantly.

2) The scope, cost & schedule for completing the design, construction and installation.

The scope of the project is well understood. The M&S cost estimate does not contain any contingency, but the largest cost items are reasonably well understood, so it is very unlikely that the current estimate is more than 50% low. The schedule uncertainty is larger.

3) Are the specifications for the cryostat sufficient to begin the bid/procurement process?

The specifications for the cryostat have not yet been written, but the conceptual design is well advanced. Similar specifications are available to use as a template. It is likely that a specification document could be written in 2-4 weeks. If Fermilab Mechanical Dept. engineers work together with Larry Bartoszek on the specification document, then no additional review will be required.

4) Is the design of the TPC specified adequately to insure its constructibility and ultimate performance?

We encourage the collaborators to continue to optimize the TPC design. The overall size and shape can be fixed now, so this process will not impact the cryostat specification.

5) Status of the electronics.

The basic electronics design is sound. The test of prototype electronics with the LArTPC in PAB is an important milestone.

6) Status of the ODH analysis - are issues related to the volume of the cryostat fully resolved?

The ODH analysis indicates that the proposed volume of liquid Argon can be safely operated in the MINOS near detector hall as an ODH Class 0 installation. We strongly recommend that relief valves be vented above ground, as in "option 2."

7) Does the design of the cryostat meet the requirements of the ODH analysis?

Yes.

8) Are the issues related to installation in the MINOS hall, in particular related to cryogenics (safety/SAD) understood and addressable?

We believe that these issues are reasonably well understood, but that it is extremely important that there be close coordination among all of the users of the Minos hall.

9) Does the project cost fit within the proposed/existing/expected budget of the project?"

We did not review a detailed cost estimate, but as stated above, we believe that there is not a large probability of significant M&S cost overrun.